

BEPCH and BESIII

Frederick A. Harris
(For the BES Collaboration)
*Dept. of Physics and Astronomy,
The University of Hawaii,
Honolulu, Hawaii 96822, USA
fah@phys.hawaii.edu*

The Beijing Electron Collider has been upgraded (BEPCH) to a two-ring collider with a design luminosity of $1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ at a center-of-mass energy of 3.78 GeV. It will operate between 2 and 4.6 GeV in the center of mass. With this luminosity, the BESIII detector will be able to collect, for example, 10 billion J/ψ events in one year of running. This will be a unique facility in the world opening many physics opportunities. BEPCH and BESIII are both currently being commissioned, first events have been obtained, and data taking will take place in fall 2008.

I. INTRODUCTION

The Beijing Electron-Positron Collider (BEPC) at the Institute of High Energy Physics (IHEP) in Beijing was, until CLEOC in 2003, a unique facility running in the tau-charm center-of-mass energy region from 2 to 5 GeV with a luminosity at the J/ψ peak of $5 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$. The Beijing Spectrometer (BES I [1] and BES II [2]) detectors at the BEPC had operated since about 1990 and studied many physics topics, including a precision measurement of the tau mass [3] and a detailed R-scan [4], and obtained 58 million events at the J/ψ , 14 million at the ψ' , and over 30 pb^{-1} at the ψ'' .

In 2003, the Chinese Government approved the upgrade of the BEPC to a two-ring collider (BEPCH) with a design luminosity approximately 100 times higher than that of the BEPC. This will allow unprecedented physics opportunities in this energy region and contribute to precision flavor physics. In this paper, BEPCH and BESIII will be described, along with their status. Additional details may be found in previous ones [5].

II. BEPCH

BEPCH is a two-ring e^+e^- collider that will run in the tau-charm energy region ($E_{cm} = 2.0 - 4.2$ GeV, but possibly as high as 4.6 GeV) with a design luminosity of $1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ at a beam energy of 1.89 GeV, an improvement of a factor of 100 with respect to the BEPC. This is accomplished mainly by using multi-bunches and micro-beta.

The 202.4 meter long linac has been upgraded with new klystrons, a new electron gun, and a new positron source to increase its energy and beam current; it can accelerate electrons and positrons up to 1.89 GeV with an positron injection rate of 62 mA/min. Its installation was completed in the summer of 2005 (see Fig. 1), and it has reached or surpassed all design specifications.

There are two storage rings with lengths of 237.5 meters. The collider has new super-conducting RF cavities, power supplies, and control; super-conducting quadrupole magnets; beam pipes; magnets and power supplies; kickers; beam instrumentation; vacuum systems; and control. The old dipoles are modified and used in the outer ring. Electrons and positrons collide at the interaction point (IP) with a horizontal crossing angle of 11 mrad and bunch spacing of 8 ns. Each ring has 93 bunches with a design beam current of 910 mA. The machine also provides a high flux of synchrotron radiation at a beam energy of 2.5 GeV.

Commissioning of the new collider with detector installed is in progress. So far, a luminosity of $1 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ and beam currents of 550 mA for both beams have been achieved.

III. BESIII

The BESIII detector consists of a beryllium beam pipe, a helium-based small-celled drift chamber, Time-Of-Flight counters (TOF) for particle identification, a CsI(Tl) crystal calorimeter, a super-conducting solenoidal magnet with a field of 1 Tesla, and a muon identifier using the magnet yoke interleaved with Resistive Plate Counters (RPC). Fig. 2 shows the schematic view of the BESIII detector, including both the barrel and end cap portions.



FIG. 1: The completed LINAC of BEPCII.

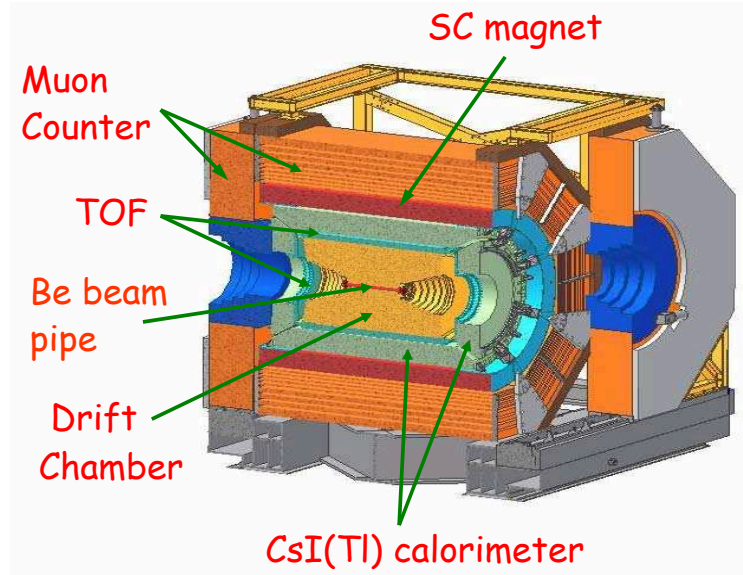


FIG. 2: Schematic view of the BESIII detector.

A. Main Drift Chamber

The main drift chamber (MDC) is 2.58 meters in length and has an inner radius of 59 mm and an outer radius of 0.81 m. The inner and outer cylinders are carbon fiber. As shown in Fig. 3, there is a short inner portion near the beam pipe, a stepped region, and a cone shaped outer region. The polar angle coverage is $\cos \theta = 0.83$ for a track passing through all layers, and $\cos \theta = 0.93$ for one that passes through 20 layers. The end-plates are machined with a hole position accuracy better than 25 microns. Altogether there are 43 layers of 25 micron gold plated tungsten sense wires; the field wires are 110 micron gold-plated aluminum. The cells are approximately square, and the size of the half-cell is 6 mm in the inner portion of the drift chamber and is 8.1 mm in the outer portion. The chamber uses a 60/40 He/ C_3H_8 gas mixture.

The design spatial, momentum, and dE/dx resolutions are $\sigma_s = 130\mu\text{m}$, $\sigma_p/p = 0.5\%$ at 1 GeV/ c , and $\sigma_{dE/dx}/dE/dx \sim 6\%$, respectively. Beam tests performed with prototype electronics at KEK in a 1 T magnetic field yielded a spatial resolution better than 110 microns and dE/dx resolution better than 5%. Tests of the final chamber and readout electronics using cosmic rays without magnetic field yield a spatial resolution of $\sigma_s = 139\mu\text{m}$ and cell efficiency of 97 %; better resolution is expected with colliding beam data and further calibration. The readout

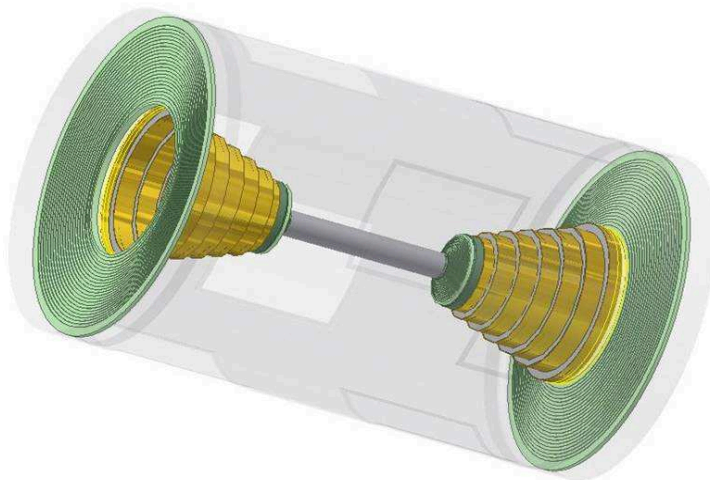


FIG. 3: Schematic view of the MDC.

uses the CERN HPTDC.

B. TOF

Outside the MDC between a radius of 810 mm and 930 mm is the time of flight (TOF) system, which is crucial for particle identification. It consists of a two layer barrel array of 88 50 mm x 60 mm x 2380 mm BC408 scintillators in each layer and end cap arrays of 48 fan shaped BC404 scintillators. Hamamatsu R5942 fine mesh photo-tubes are used - two on each barrel scintillator and one on each end cap scintillator. Expected time resolution for kaons and pions and for two barrel layers is 100 to 110 ps, giving a 2σ K/π separation up to 0.9 GeV/c for normal tracks. This resolution has been confirmed in a beam test of a TOF counter using prototype electronics. A TOF monitoring system featuring a 440 nm laser diode and specially designed fiber optic bundles was built by the University of Hawaii, IHEP, and the University of Science and Technology of China [6].

C. Calorimeter

The CsI(Tl) crystal calorimeter contains 6240 crystals total in the barrel and end cap portions of the calorimeter. The typical crystal is 5.2×5.2 cm² on the front face and 6.5×6.5 cm² on the rear face with a length of 28 cm or 15 radiation lengths. Figure 4 shows a schematic of the assembly containing an aluminum plate with two photo-diodes (Hamamatsu S2744-08) with 10 mm by 20 mm sensitive area and an aluminum box for the two preamps and amplifier mounted on the end of a crystal. The design energy and spatial resolutions at 1 GeV are 2.5 % and 0.6 cm, respectively, and the energy range will extend as low as 20 MeV.

Figure 5 shows barrel electromagnetic calorimeter inside the superconducting magnet. The crystals are held by screws and there are no walls between crystals.

D. Magnet

The BESIII super-conducting magnet is the first of its kind built in China. It is a 3.91 m long single layer solenoid with a 1 T magnetic field at a nominal current of 3369 A. Fig. 6 shows the magnet during field mapping in June 2007, done with the super conducting quadrupoles in place, using a computer controlled mapping machine. The measured field in the MDC has an accuracy better than 0.25 % and was measured with a position accuracy of 0.5 mm.

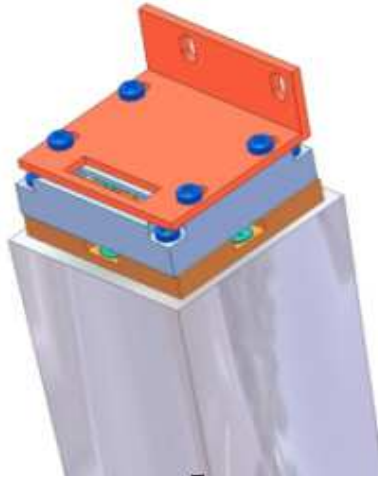


FIG. 4: Schematic of the photo-diode and preamp assembly on the end of an electromagnetic calorimeter crystal.



FIG. 5: Assembled barrel electromagnetic calorimeter inside the superconducting magnet.

E. Muon Counter

The magnet return iron has nine layers of Resistive Plate Chambers (RPC) in the barrel and eight layers in the end cap to form a muon counter, which can be seen in Fig. 6. The electrodes of the RPCs are made from a special phenolic paper laminate on Bakelite, which has a very good surface quality. The gas used is Ar : $C_2H_2F_4$: Isobutane (50:42:8). Extensive testing and long term reliability testing have shown that the chambers have high efficiency, low dark current, and good long term stability. The RPCs use 4 cm wide one dimensional readout strips, and about 10,000 channels of readout are required.

F. Trigger, Data Acquisition, and Offline Software

The trigger is pipelined and uses FPGAs. Information from the TOF, MDC, and muon counter are used. The maximum trigger rate at the J/ψ will be about 4000 Hz with a good event rate of about 2000 Hz.

The whole data acquisition system has been tested to 8 kHz for an event size of 12 Kb, which is a safety margin of a factor of two. The expected bandwidth after level one is 50 Mbytes/s. The data acquisition system has 1000 times

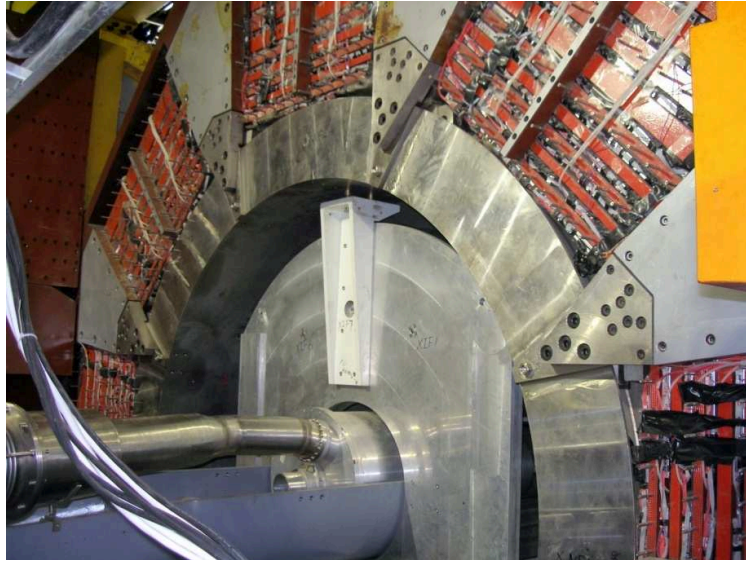


FIG. 6: The magnet during field mapping, done with the super conducting quadrupoles in place, using a computer controlled mapping machine during 2007. Outside the magnet, the return steel and RPC chambers of the muon counter are visible.

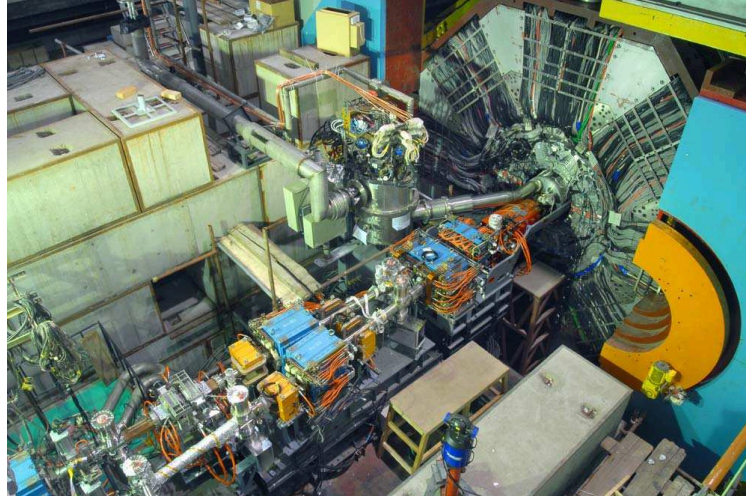


FIG. 7: BESIII detector at the IP in June 2008. Shown are a superconducting quadrupole, the two beam lines, and the BESIII detector with the magnet iron open and end caps exposed.

the performance of BESII.

The BES Offline Software System (BOSS) is complete. Simulation is based on Geant4.

G. Status

In March 2008, a two month long cosmic ray run without magnetic field was completed. This run was extremely useful for commissioning the detector and doing initial calibrations and performance checks.

The detector then moved to the IP and is shown in Fig. 7 at its final location in June 2008 with all beam magnets and vacuum pipes in place.

Commissioning of the detector and collider together began in July, and the first hadronic event was obtained on July 19, 2008 (see Fig. 8). Data taking will begin in early fall.

The BESIII collaboration includes physicists from IHEP, many Chinese Universities, and groups from Germany, Japan, Russia, and the U.S.

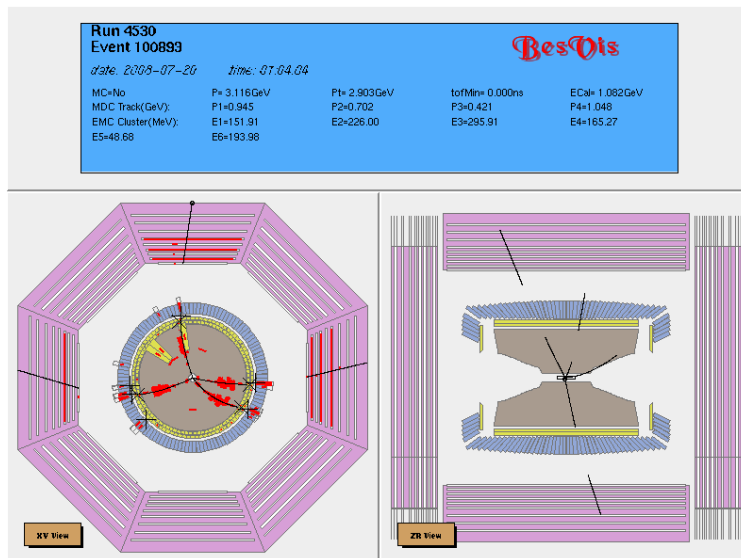


FIG. 8: Online display of the first hadronic event recorded by the BESIII detector on July 19, 2008.

IV. PHYSICS IN THE TAU-CHARM ENERGY REGION

The tau-charm energy region makes available a wide variety of interesting physics. Data can be taken at the J/ψ , $\psi(2S)$, and $\psi(3770)$, at $\tau^+\tau^-$ threshold, and at an energy to allow production of D_S pairs, as well as for an R-scan. The $\psi(3770)$ is an ideal factory for producing $D\bar{D}$ pairs, and the $\psi(2S)$ allows access to η_c , h_c , and χ_c physics via radiative and hadronic transitions.

TABLE I: Number of events expected for one year of running.

Physics channel	Center-of-mass Energy (GeV)	Peak Luminosity ($10^{33} \text{ cm}^{-2} \text{ s}^{-1}$)	Physics cross section (nb)	Number of Events per year
J/ψ	3.097	0.6	~ 3400	10×10^9
τ	3.67	1.0	~ 2.4	12×10^6
$\psi(2S)$	3.686	1.0	~ 640	3.0×10^9
D	3.770	1.0	~ 5	25×10^6
D_S	4.030	0.6	~ 0.32	1.0×10^6
D_S	4.140	0.6	~ 0.67	2.0×10^6

Clearly BESIII with higher a luminosity of $1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ will contribute greatly to precision flavor physics; V_{cd} and V_{cs} will be measured with a statistical accuracy of better than 1.0%. $D^0\bar{D}^0$ mixing will be studied, and CP violation will be searched for. Table I gives the numbers of events expected during one year of running at various energies. Huge J/ψ and $\psi(2S)$ samples will be obtained. The η_c , χ_{cJ} , and h_c can be studied with high statistics. The $\rho\pi$ puzzle will be studied with better accuracy. The high statistics will allow searches for physics beyond the standard model. The future is very bright.

V. ACKNOWLEDGMENTS

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